

Circuit measures capacitance or inductance

Use instruments you already have and a few equations when you don't have a capacitance meter.

By Jim McLucas, Broomfield, CO

Engineers usually have access to signal and function generators, as well as frequency counters and oscilloscopes, but they may not have access to capacitance or inductance meters. Using the test setup illustrated in the **figure**, you can measure capacitance or inductance using a function generator, a multimeter, a frequency counter, and an oscilloscope.

Use the setup to measure the magnitude of two signals. You can then calculate the capacitance or inductance without measuring phase angles. You can express the ratio of input voltage to output voltage as:

$$\left| \frac{V_{IN}}{V_{OUT}} \right| = \frac{\sqrt{R^2 + X_C^2}}{X_C} \quad (1)$$

which you can put into the standard form:

$$X_C^2 + \frac{R^2}{1 - \left| \frac{V_{IN}}{V_{OUT}} \right|^2} = 0 \quad (2)$$

After solving the equation for X_C , the result is:

$$X_C = \frac{R}{\sqrt{\left| \frac{V_{IN}}{V_{OUT}} \right|^2 - 1}} \quad (3)$$

Using the relationship

$$C = \frac{1}{2\pi f X_C} \quad (4)$$

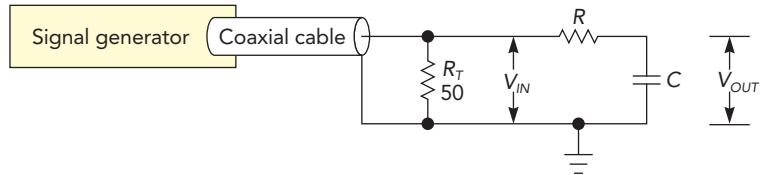
the basic equation for capacitance is:

$$C = \frac{\sqrt{\left| \frac{V_{IN}}{V_{OUT}} \right|^2 - 1}}{2\pi f R} \quad (5)$$

Using the convenient ratio $|V_{IN}/V_{OUT}| = 2$, then

$$C = \frac{\sqrt{3}}{2\pi f R} \quad (6)$$

To measure the value of a capacitor, measure the input voltage and then adjust the frequency of the signal generator to make the output voltage one half of the input voltage. You



You can measure capacitance or inductance with this test setup.

need not use a 2-to-1 ratio for V_{IN}/V_{OUT} . You can just measure the input voltage and the output voltage and use one of the basic equations to calculate the value of the capacitance or inductance, but a ratio close to 2-to-1 is a good choice.

For best results, you can use a frequency counter to measure the frequency and a digital multimeter to measure the resistance. Most modern oscilloscopes can accurately measure the signals without loading the circuit, except for the capacitance of the probe. Capacitance is usually marked on the probe. Use the previous equation to calculate the value of the capacitor. Subtract the value of the probe capacitance from the result, and you have an accurate value for the measured capacitance.

Usually, you know the approximate value of the capacitance you want to measure, so you can pick a starting value for the resistance, R , and the frequency, f , by using these equations:

$$R = \frac{\sqrt{3}}{2\pi f C} \quad (7)$$

$$f = \frac{\sqrt{3}}{2\pi R C} \quad (8)$$

$$X_C = \frac{R}{\sqrt{3}} \quad (9)$$

You can use a similar procedure to measure inductance. In this case,

$$X_L = \frac{R}{\sqrt{\left| \frac{V_{IN}}{V_{OUT}} \right|^2 - 1}} \quad (10)$$

and the basic equation for inductance is expressed as:

$$L = \frac{R}{2\pi f \sqrt{\left| \frac{V_{IN}}{V_{OUT}} \right|^2 - 1}} \quad (11)$$

Set $V_{IN}/V_{OUT} = 2$, then

$$L = \frac{R}{2\pi f\sqrt{3}} \quad (12)$$

$$R = 2\pi fL\sqrt{3} \quad (13)$$

$$f = \frac{R}{2\pi L\sqrt{3}} \quad (14)$$

$$X_L = \frac{R}{\sqrt{3}} \quad (15)$$

For an example of measuring capacitance, assume C is approximately equal to 1000 pF and let f equal 1 MHz. Calculate as:

$$R = \frac{\sqrt{3}}{2\pi fC} = \frac{\sqrt{3}}{2\pi(10^6)(10^{-9})} = 275.66 \, \Omega \quad (16)$$

Use a 301- Ω resistor or any convenient value of approximately 250 Ω to 500 Ω in the setup shown in the figure. Adjust the frequency while measuring the input voltage and the output voltage to get a ratio of 2-to-1. If the frequency you obtain is 912 kHz, the measured resistance of R is 304 Ω , and the probe capacitance is 10 pF, then the capacitance is:

$$C = \frac{\sqrt{3}}{2\pi(912)(10^3)(304)} = 994.3 \, \text{pF} \quad (17)$$

minus 10 pF for the probe capacitance. The result is 984.3 pF.

The values for R and f are not critical; you should choose them to minimize parasitic effects. Resistance values of 300 Ω to 3000 Ω and frequencies of 100 kHz to 1 MHz should work. T&MW

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